

Relation between Cotinine in the Urine and Indices Based on Self-Declared Smoking Habits

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Abstract

Objectives: The reliability of surveys on smoking habits based on questionnaires was investigated, using the urinary cotinine content as an objective index.

Methods: The subjects tested were 2,849 office workers of middle age, who responded to questions concerning their smoking status, and also their urinary cotinine was measured by the HPLC method.

Results: The boundary value between smokers and non-smokers, determined by the histogram independent of the questionnaire, was 63.1 and 79.4 ng/mg of creatinine for males and females, respectively. The rate of misclassification of the non-smokers and former smokers as smokers was 1.3% for males and 1.8% for females, whereas that of current smokers as non-smokers was 6.3% and 2.1%. We also assessed the effect of smoke inhalation on the urinary cotinine value, and found a significant difference for males in the cotinine value by the presence of inhalation and also its depth.

Conclusions: The rate of misclassification in this study was considered to be comparatively low. Several studies have also assessed the reliability of the questionnaire on smoking habits, and found different misclassification rates, indicating the dependence on the race and number of subjects tested. To our knowledge, there were only a few surveys on smoking among large groups, particularly in Japan, such as this one, therefore the results obtained in this study are meaningful.

Key words: smoking habits, urinary cotinine level, reliability of questionnaires, misclassification, Japanese

Introduction

The results of numerous studies have confirmed that smoking is a serious risk factor for many diseases, such as those affecting the circulatory and respiratory systems, and malignancies¹. To acquire accurate information on the smoking status of a population, questionnaires filled out by individuals are commonly used; but their reliability is often disputed. In particular, the problem of misclassification is a serious problem²: smokers may pretend to be non-smokers or they may lie about the number of cigarettes they smoke, which may affect the accuracy of the survey that is intended to shed some light on the health effects of smoking.

For objective biological indices of smoking status, nicotine, cotinine (a metabolite of nicotine), thiocyanate, carboxylated hemoglobin, and carbon monoxide in the exhaled air have been used^{3,4}. Among them, cotinine is highly specific for tobacco smoke, exists in the urine in a concentration that is high enough to

measure, and its half-life is relatively long (10 to 20 hours)⁵. Therefore, its urinary concentration is considered to be a useful index that objectively shows (either active or passive) smoking status⁶.

In the present study, the urinary cotinine concentration was used as an index to investigate the reliability of a smoking survey using a questionnaire in which individuals report on their smoking habits. In addition, the relation between the urinary cotinine level and the manner of smoking (tobacco smoke inhalation, extent of inhalation, and how far down the length of each cigarette is smoked) was investigated.

Subjects and Methods

Population group

Between 1990 and 1997, a survey was conducted annually on 2,849 employees (aged 35, 40, 45, 50, and 55 years) of a business office in Tokyo. The survey included a self-administered questionnaire on smoking habits and the collection of urine samples. For the smoking habits, the employees were asked to respond to questions on: smoking habits, the number of cigarettes smoked, and the manner of smoking. The completed questionnaire was retrieved at the employee's health examination. On the same day, each employee was asked to bring in his urine sample that was passed

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first in the morning (considered to reflect the daily cotinine content most accurately). The cotinine concentration was analyzed in this urinary sample, which had been freeze-preserved at -20°C until analysis.

Questionnaire on smoking habits

The current smokers were defined as those who responded affirmatively to questions: "Do you now or have you previously smoked cigarettes?" "Have you smoked more than one cigarette a day continually for more than one year?" and "Are you currently a smoker?" Former smokers were those who responded affirmatively to the first two of these questions but negatively to the last. Conversely, the non-smokers were defined as those who responded negatively to all three questions. The type of tobacco smoked was checked from a list that included "cigarettes, cigars, pipe tobacco, shredded tobacco, and others".

The number of cigarettes smoked was the mean per day. For those who responded affirmatively to the question on tobacco smoke inhalation, another question was posed to classify the extent of inhalation to one of 3 levels—slight, intermediate, or deep. Another question was asked about the extent to which each cigarette was consumed and was classified also to one of 3 levels—less than half (1/2), half (1/2) to three quarters (3/4), or very near to the end.

Passive smokers were those who responded affirmatively to the question, "Is there a smoker(s) in your family?" or "Is the air in your office polluted with tobacco smoke from smokers there?" Those who responded negatively to these two questions were regarded as "free of passive smoking".

Urinary cotinine measurement

The cotinine content was determined in 5 ml of a urine sample by employing the HPLC method⁹. The result was adjusted for creatinine and the urinary cotinine/creatinine (Cr) ratio (ng/mg Cr) was used as the urinary cotinine level. The detectable urinary cotinine threshold (according to this method) was less than 5 ng/ml and the detectable threshold after creatinine adjustment was set at 1.0 ng/mg Cr.

Compilation and statistical analysis

For compilation and statistical analysis, SAS for Windows version 6.12 (SAS Institute Inc., USA) was used. Since the survey was conducted annually for 8 years on those who were 35–, 40–, 45–, 50–, and 55-years-old, multiple and duplicate surveys on the same subjects (17.2% of the total) occurred. However, this study was basically static in nature and there is a strong possibility that the smoking habits of individuals changed over the years. Therefore, the study involved all subjects, even those who responded more than once over the 8-year period.

Results

Recovery rate

The survey involved 2,039 males and 810 females altogether. The number of respondents and the mean recovery rate were: 1,624 and 79.6% for males and 735 and 90.7% for females. The urinary samples were collected from 1,872 males (91.8%) and 775 females (95.7%).

Smoking status

Table 1 shows the smoking status (by gender and year when

Table 1 Status of smoking by year of survey and gender

Males								
Year of survey	Current smokers		Former smokers		Non-smokers		Total	
	Number	%	Number	%	Number	%	Number	%
1990	70	39.8	44	25.0	62	35.2	176	100.0
1991	63	39.9	41	25.9	54	34.2	158	100.0
1992	95	42.2	56	24.9	74	32.9	225	100.0
1993	53	31.0	45	26.3	73	42.7	171	100.0
1994	71	40.8	48	27.6	55	31.6	174	100.0
1995	55	31.4	40	22.9	80	45.7	175	100.0
1996	63	35.2	44	24.6	72	40.2	179	100.0
1997	68	34.0	50	25.0	82	41.0	200	100.0
Total	538	36.9	368	25.2	552	37.9	1,458	100.0
Females								
Year of survey	Current smokers		Former smokers		Non-smokers		Total	
	Number	%	Number	%	Number	%	Number	%
1990	7	9.5	2	2.7	65	87.8	74	100.0
1991	3	4.1	2	2.7	68	93.2	73	100.0
1992	9	11.4	0	0.0	70	88.6	79	100.0
1993	9	10.2	2	2.3	77	87.5	88	100.0
1994	10	11.0	6	6.6	75	82.4	91	100.0
1995	6	6.5	4	4.3	82	89.1	92	100.0
1996	5	5.7	2	2.3	81	92.0	88	100.0
1997	8	8.2	1	1.0	89	90.8	98	100.0
Total	57	8.3	19	2.8	607	88.9	683	100.0

Those who were ambiguous were not included.

Table 2 Responses by smokers by age to the question “Do you inhale?”

Males							
Age	Yes		No		Total		*
	Number	%	Number	%	Number	%	
35	103	92.0	9	8.0	112	100.0	0
40	108	92.3	9	7.7	117	100.0	0
45	110	86.6	17	13.4	127	100.0	1
50	100	81.3	23	18.7	123	100.0	1
55	32	72.7	12	27.3	44	100.0	0
Total	453	86.6	70	13.4	523	100.0	2

Females							
Age	Yes		No		Total		*
	Number	%	Number	%	Number	%	
35	19	95.0	1	5.0	20	100.0	0
40	20	100.0	0	0.0	20	100.0	0
45	7	100.0	0	0.0	7	100.0	0
50	5	83.3	1	16.7	6	100.0	0
55	1	33.3	2	66.7	3	100.0	1
Total	52	92.9	4	7.1	56	100.0	1

* Those who did not answer the question.

each survey was conducted) of those who responded to the questionnaire. The rate of the current smokers was 36.9% for males and 8.3% for females. Over the 8-year period, the rate decreased slightly for males; but for females it remained at a plateau with occasional, slight deviations. The rate of non-smokers increased slightly for both males and females. For the type of tobacco smoked, cigarettes were smoked by 97.6% of the males (n=525) and 100% of the females (n=57). Therefore the following analysis was limited to the current smokers of cigarettes.

The number of cigarettes smoked per day by male smokers was less than 10 for 66 (12.6%) (less than 5 for 28), 11 to 20 for

214 (40.8%), 21 to 40 for 207 (39.4%), more than 41 for 37 (7.0%), and no response for one (0.2%). Among female smokers, the number was less than 10 for 39 (68.4%) (less than 5 for 13) and 11 to 20 for 18 (31.6%) but none smoked more than 21.

Among males, 86.9% stated that they inhale the tobacco smoke into the lungs while smoking, while 13.4% responded otherwise. Of the female smokers, 92.9% stated that they inhale it into the lungs and 7.1% responded otherwise. Both males and females appear to inhale less as they grow older (Table 2). Of the male inhalers of tobacco smoke, 16.1% responded that they inhale smoke deeply into the lungs. This figure was considerably greater than the corresponding one for females (5.8%, Table 3). When compared among different ages, both males and females appear to inhale more lightly as they grow older. For the extent of smoking each cigarette, about 70% (for both genders) smoked 1/2 to 3/4 of the length of each (Table 4). None of the women smoked to the very end.

Distribution of urinary cotinine level and misclassification of smoking habits stated in the questionnaire

Urinary cotinine levels could be determined for the current smokers (477 males and 48 females), non-smokers (482 males and 485 females), and former smokers (333 males and 14 females), all according to the responses given in the questionnaire. These levels showed as double-peaked histograms, with the left peak corresponding mainly to the non- and former smokers and the right peak, mainly to the current smokers. Thus, there was an unevenness in the distribution of the urinary cotinine values (Figure 1).

For normal distribution approximation, we conducted modeling by calculating a set of mean values that would minimize the residual error from observations and calculate the variance using the mean square deviation from these means, and then we determined the intersection of the two resultant curves. For males, it was about 1.8 Log (ng/mg Cr) and for females, it was 1.9 Log (ng/mg Cr). These values were used as a threshold to determine the current smoking practice. These values were converted to 63.1 ng/

Table 3 Depth of inhaling, by age, of smokers who admitted that they inhale

Males										
Age	Slight		Intermediate		Deep		Total		*	
	Number	%	Number	%	Number	%	Number	%		
35	34	33.7	52	51.5	15	14.9	101	100.0	2	
40	32	30.2	58	54.7	16	15.1	106	100.0	2	
45	32	29.4	55	50.5	22	20.2	109	100.0	1	
50	33	33.3	53	53.5	13	13.1	99	100.0	1	
55	14	43.8	12	37.5	6	18.8	32	100.0	0	
Total	145	32.4	230	51.5	72	16.1	447	100.0	6	

Females										
Age	Slight		Intermediate		Deep		Total		*	
	Number	%	Number	%	Number	%	Number	%		
35	6	31.6	11	57.9	2	10.5	19	100.0	0	
40	11	55.0	8	40.0	1	5.0	20	100.0	0	
45	2	28.6	5	71.4	0	0.0	7	100.0	0	
50	3	60.0	2	40.0	0	0.0	5	100.0	0	
55	1	100.0	0	0.0	0	0.0	1	100.0	0	
Total	23	44.2	26	50.0	3	5.8	52	100.0	0	

* Those who did not answer the question.

Table 4 Response by smokers, by age, to the question “How far down do you smoke a cigarette?”

Males									
	Less than half way down		Half way to three-quarters down		Very near to the end		Total		*
Age	Number	%	Number	%	Number	%	Number	%	Number
35	24	21.4	85	75.9	3	2.7	112	100.0	0
40	23	19.7	87	74.4	7	6.0	117	100.0	0
45	29	22.7	91	71.1	8	6.3	128	100.0	0
50	30	24.2	88	71.0	6	4.8	124	100.0	0
55	8	18.2	35	79.5	1	2.3	44	100.0	0
Total	114	21.7	386	73.5	25	4.8	525	100.0	0

Females									
	Less than half way down		Half way to three-quarters down		Very near to the end		Total		*
Age	Number	%	Number	%	Number	%	Number	%	Number
35	6	30.0	14	70.0	0	0	20	100.0	0
40	4	20.0	16	80.0	0	0	20	100.0	0
45	3	42.9	4	57.1	0	0	7	100.0	0
50	4	66.7	2	33.3	0	0	6	100.0	0
55	1	25.0	3	75.0	0	0	4	100.0	0
Total	18	21.7	39	68.4	0	0	57	100.0	0

* Those who did not answer the question.

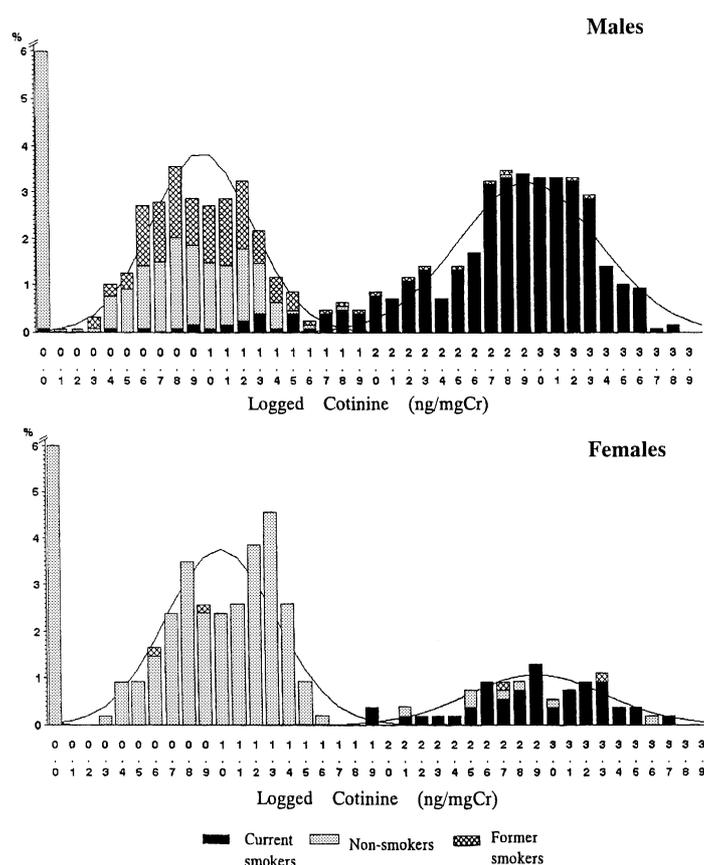


Fig. 1 Distribution of cotinine value in the urine of all respondents by smoking habits and by gender. Three classifications for the smoking habit (Current, Former, Non-smokers) are based on the answers to the questionnaire.

mg Cr for males and 79.4 ng/mg Cr for females.

Next, the frequency of misclassification of smoking habits reported in the questionnaires was examined according to these threshold values. The rates of males and females who stated that they were non-smokers or former smokers but were classified as

smokers according to urinary cotinine levels were 1.3% and 1.8%, respectively. The rates of those who stated that they were current smokers in the questionnaire but were classified as non-smokers according to urinary cotinine levels were 6.3% for males and 2.1% for females (Table 5).

Table 5 Classification with the boundary value of urinary cotinine and the frequency of misclassification according to smoking habits

Males	cotinine value			
	Total number	63.1 ng/mg Cr or more	Less than 63.1 ng/mg Cr	Misclassification ratio (%)
Current smokers	477	447	30	6.3 (30/477)
Former smokers	333	9	324	2.7 (9/333)
Non-smokers	482	2	480	0.4 (2/482)
Former smokers+Non-smokers	815	11	804	1.3 (11/815)

Females	cotinine value			
	Total number	79.4 ng/mg Cr or more	Less than 79.4 ng/mg Cr	Misclassification ratio (%)
Current smokers	48	47	1	2.1 (1/48)
Former smokers	14	2	12	14.3 (2/14)
Non-smokers	485	7	478	1.4 (7/485)
Former smokers+Non-smokers	499	9	490	1.8 (9/499)

Number of cigarettes smoked and urinary cotinine level

A scatter diagram was prepared for the male and female current smokers, assigning the urinary cotinine level to the ordinate and the number of cigarettes smoked to the abscissa (Figures 2 and 3). A significant correlation was noted between the number of cigarettes smoked and the Log of urinary cotinine concentration ($r=0.407$, $p<0.05$ for males and $r=0.535$, $p<0.05$ for females).

The "manner of smoking" and urinary cotinine value

Table 6 shows the results of the analysis on the effect of the manner of smoking that is exerted on urinary cotinine values (adjusted for age and the number of cigarettes smoked). The results from an analysis of covariance showed a significant difference in the Log (ng/mg Cr) of urinary cotinine when male smokers inhaled the tobacco smoke into the lungs (F value, 5.62, $p < 0.05$).

No such difference was noted in the findings for females.

Next, an analysis of covariance was conducted on the effect of the degree of inhalation on the urinary cotinine level for the male inhalers. The analysis showed a significant difference that depended on the degree of inhalation (F value, 13.64, $p<0.05$). No difference was found among female inhalers. For the relation with the extent of smoking each cigarette, no significant difference was noted in the urinary cotinine levels for either males or females.

For the males who showed a significant difference in the urinary cotinine value, the relation between the number of cigarettes smoked and the urinary cotinine level was plotted according to the depth of inhaling (Figure 4).

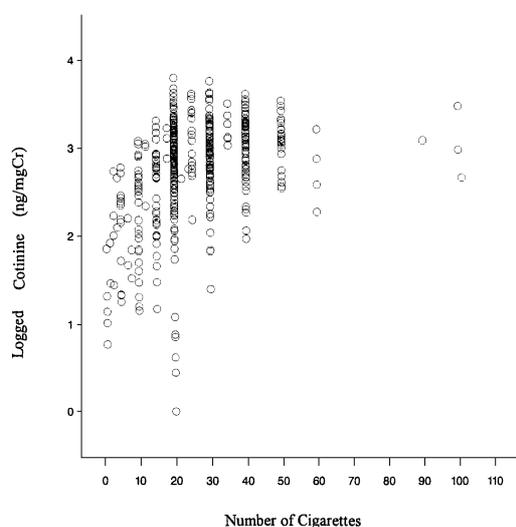


Fig. 2 Cotinine value in the urine vs. number of cigarettes smoked (males).

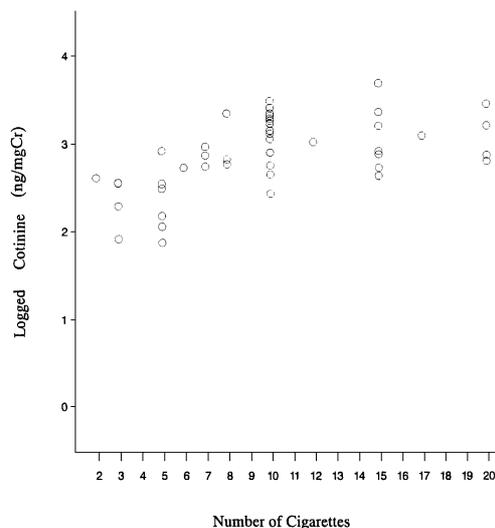


Fig. 3 Cotinine value in the urine vs. number of cigarettes smoked (females).

Table 6 Influence of smoking habits on the urinary cotinine value adjusted for age and number of cigarettes smoked

	Males		Females	
	F value	P value	F value	P value
Do you inhale?	5.62	0.0182**	2.55	0.1179
Depth of inhaling	13.64	0.0001**	0.49	0.614
How far down do you smoke the cigarette?	0.28	0.7592	0.08	0.7833

–Do you inhale?: Yes No

–Depth of inhaling: Slight Intermediate Deep

–How far down do you smoke each cigarette?: Less than half way Half way to three-quarters down Very near to the end

Determination of significant difference (covariance analysis).

** P value<0.05.

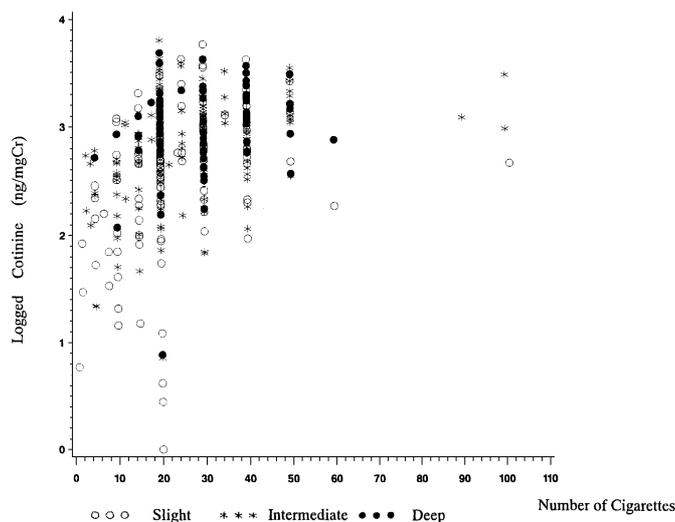


Fig. 4 Relation between the number of cigarettes smoked and the cotinine value in the urine according to depth of inhaling (males).

Discussion

To find whether a person is a smoker or non-smoker, or a non-smoker is being exposed to environmental tobacco smoke (ETS), and to evaluate the extent of tobacco smoke exposure, blood and urinary nicotine or cotinine (a nicotine metabolite) levels can be measured. However, compared with nicotine, the half-life of urinary cotinine is long (10 to 20 hours) so it is more commonly determined¹⁰. In the present study, the responses to the questionnaire and the distribution of the urinary cotinine levels were compared in a relatively large group to examine the reliability of self-disclosure of smoking habits.

It was found that when plotted, the urinary cotinine distribution among current smokers and non-smokers (including former smokers, according to responses given in the questionnaire) appeared as a two-peak pattern, in which the left peak mainly represented non-smokers (non- and former smokers) and the right peak, current smokers. A histogram was then prepared and the point where the two curves intersected was determined. The value was found to be 63.1 ng/mg Cr for males and 79.4 ng/mg Cr for females, both of which are considered to constitute the boundary values that differentiate smokers from non-smokers in this study.

There is a boundary value method in which questionnaires and biological indices (such as a cotinine level) are used; and smoking and non-smoking are differentiated by a cut-off value to raise both the sensitivity and specificity¹¹. In the present study, it was confirmed that the urinary cotinine distribution has two

distinct peaks, thus separating the smokers and non-smokers into two groups. The boundary value thus obtained does not rely on the responses by individuals and is therefore purely objective. Haufroid et al. examined a study on urinary cotinine values that were used to indicate tobacco smoke exposure and reported that the threshold that differentiates active smokers from passive smokers is in the range of 20 to 100 ng/ml (or ng/mg Cr)¹⁰. Takeda stated that the urinary cotinine boundary value that differentiates smokers from non-smokers is approximately 80 to 120 ng/mg Cr¹². The value we arrived at in the present study approximates those given above.

Eleven males (1.3%) and 9 females (1.8%) stated that they were non-smokers or former smokers; but from their urinary cotinine values they were classified as smokers. Among them, 2 males (0.4%) and 7 females (1.4%) were judged to be current smokers (despite their response on the questionnaire); and 9 males (2.7%) and 2 females (14.3%) were former smokers but judged to be current smokers. There are several studies from other countries of a similar nature that compare responses from a questionnaire and biological indices^{13–23}. The indices used in these studies varied (urinary cotinine or nicotine^{13–15}, serum or plasma cotinine^{16–20}, and salivary cotinine^{21–23}) but the rate of misclassification (non-smoker according to the questionnaire being judged to be a smoker according to the biological index) in these studies was reported to range from 0 to 10%. Among them, two studies in which the urinary cotinine level was used as an index, gave a misclassification rate of 0.9%^{14,15}, which is slightly lower than that obtained in the present study (1.3% for males and 1.8% for females). However, the cut-off values used in these studies were higher (175 ng/ml¹⁴ and 90 ng/ml¹⁵) than used in the present study (63.1 ng/mg Cr for males and 79.4 ng/mg Cr for females), which may explain the low rate of misclassification in their studies. Furthermore, the number of participants (former smokers and non-smokers) in these studies was less (221¹⁴ and 669¹⁵) than in the present study (a total of 1,314, 815 males and 499 females). This difference in the number of test subjects may also be a reason for a low rate of misclassification. As reported previously racial differences may be another cause for a discrepancy. In a study conducted in the United States of America in which caucasians and negroes were evaluated separately, the rate of misclassification was slightly higher among the latter²⁰. The same study also reported that in addition to racial factors, parameters such as the level of education attained (the rate is higher for those with a 12th grade education or less and lower among university graduates) and past smoking history (higher among former smokers and lower among those who have not smoked at all) will affect the misclassification of individuals within a group²⁰. Nicotine is converted to

cotinine by cytochrome P450 (CYP) 2A6, and according to a recent study, individuals who had genetic homozygous CYP2A6 deletion had decreased urinary cotinine excretion despite smoking²⁴). This genetic factor also may be involved in the misclassification rate.

Among the group in the present study, the rate of misclassification was higher among former smokers in comparison with non-smokers. The rate of misclassification here was relatively low when compared against 0–10% reported by others^{13–23}). The reason for this, in addition to the racial difference, may be due to the finding that the group was composed of white-collar workers and a large percentage were college graduates. These characteristics resemble those of a similar study by Terao et al., who also observed Japanese subjects: although carbon monoxide in the exhaled air was used as an index, they cited a misclassification rate of 1.2%¹¹).

As shown in Figure 1, 30 males (6.3%) who stated that they were current smokers in the questionnaire were classified as non-smokers based on their urinary cotinine level: 10 of them smoked less than 5 cigarettes a day. Of the remaining 20, 8 smoked 6 to 10 cigarettes; 11 smoked 11 to 20; and one smoked more than 21. It has been reported that the urinary cotinine level of non-smokers who are in a polluted environment from tobacco smoke corresponds to that of smokers who smoke up to 3 cigarettes per day⁶). There is a possibility that those who smoke less than this may be classified as non-smokers. The probability that those who smoke 4 or more cigarettes a day will be classified as non-smokers may be explained by a temporary reduction in tobacco consumption for some reason or an attempt to stop smoking. Among females, only one smoker (2.1%) (stated in the questionnaire) was misclassified as a non-smoker. She smoked 5 cigarettes a day.

The non-smokers who reported that they were exposed to tobacco smoke at their workplace were compared against those who were not. The percentage of those showing a cotinine level that exceeded the detectable threshold was higher among the passive smokers, showing a difference in the distribution of the cotinine level. However, no distinctive boundary was found to distinguish passive smoking among either male or female non-smokers. It is probable that non-smokers are being exposed to tobacco smoke at various sites more frequently than they were aware.

Urinary cotinine is used widely as a biological indicator of active and passive smoking. However, because nicotine is contained in several foods, such as eggplant, potatoes and tomatoes^{25,26}), any consumption of these foods may affect the urinary cotinine level. Except for strict vegetarians, it is understood that the average daily consumption of these foods will not substantially affect the test result. However, it may be necessary to consider the dietary regimen when setting a boundary value to determine the possibility for passive smoking.

As we were able to evaluate the criteria to determine smoking based on the urinary cotinine level, we next examined the reliability of the number of cigarettes smoked as given in the questionnaire. It may be necessary to consider the amount of nicotine contained in each cigarette but the recent trend in Japan has been to sell products with a low nicotine content: the average content for tobacco sold in Japan has been reduced from 1.6 mg in 1969 to

the recent 1 mg¹). Since a smoker's preference for particular brands has generally been standardized, a survey to measure the nicotine content in each cigarette was not conducted. As shown in Figures 2 and 3, significant correlations were noted in the number of cigarettes smoked and the urinary cotinine level for both males ($r=0.458$, $p<0.05$) and females ($r=0.564$, $p<0.05$).

The urinary cotinine level was scattered over a fairly wide range among individuals who smoked identical numbers of cigarettes; and the urinary cotinine level for those who smoked more than 40 cigarettes did not increase as much as expected. Therefore, the effect of the manner of smoking (inhalation of tobacco smoke classified into 3 levels) on the urinary cotinine level was examined. Since an age-related difference was noted (Tables 2 and 3), an adjustment for the age and number of cigarettes smoked was made first, then a covariance analysis was conducted. It was found that in males, the inhalation of smoke, as well as the depth of inhalation, significantly increased the urinary cotinine level ($F=5.62$, and $F=13.64$, both $p<0.05$, respectively, Table 6). Among females, the inhalation of tobacco smoke and depth of its inhalation did not produce any significant difference.

In a recent study on Japanese male smokers, it was reported that the depth of tobacco smoke inhalation independently showed a significant correlation with the serum cotinine level²⁷), which coincided with the findings of the present study. The question of how far down (in length) an individual smokes each cigarette was then examined; but in both male and female smokers, there was no significant difference in relation to this aspect of smoking behavior. The reason may be that defining the length of a cigarette smoked was somewhat ambiguous; individual smokers were not very aware of it; or the length of the cigarette smoked may have varied, dependent on each situation and the mood that the smoker happens to be in at the time. In addition, 70% of both male and female smokers stated that they smoke "1/2 to 3/4" of each cigarette; and none of the female smokers reported smoking to the very end of the cigarette (Table 4). It is possible that there was a bias in the 3 categories assigned to the length of a cigarette smoked (and the number of smokers assigned to these categories).

The urinary cotinine level failed to show increases despite the large number of cigarettes smoked. As shown in Figure 2, 8 stated that they smoked more than 60 cigarettes a day: only one of them inhaled the tobacco smoke deeply into his lungs and none smoked each cigarette to the very end. It is presumed that those who smoke a large number of cigarettes, the so-called chain-smokers, did not smoke them to the end; thus the actual amount of nicotine intake was not as high as expected.

Conclusions

The frequency of misclassification of smoking habits reported in questionnaires was examined, based on the relation between the indices for self-reported smoking habits (subjective indices) and the urinary cotinine level (objective index). The percentage of non- or former smokers according to the questionnaire who were classified as smokers was 1.3 for males and 1.8 for females. The percentage of current smokers (according to the questionnaire responses) who were classified as non-smokers was 6.3 for males and 2.1 for females.

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